INTELLIGENT ROUTING WITHIN WIRELESS COMMUNICATION SYSTEMS

The present invention generally relates to wireless communication systems, and more particularly, to systems and methods for intelligent routing within wireless communication systems.

Conventional wireless communication systems typically employ a network configuration protocol, such as the Dynamic Host Configuration Protocol (DHCP), to automate the connection and configuration of client/server devices. These protocols may be used, for example, to automatically assign IP addresses, to deliver TCP/IP stack configuration parameters, and to provide other configuration information such as addresses of shared resources and characteristics of the client/server devices connected to the network. As a result, these approaches provide significant advantages in terms of flexibility and ease of use by enabling users to add device to (or remove devices from) the wireless network and move devices around the wireless network without requiring the user to manually reconfigure IP settings.

These approaches, however, can produce sub-optimal results due to the relatively static and ad hoc manner in which the network topology is determined. For example, these approaches typically require client/server devices to select a router or gateway to associate with at the time the device initially connects to the network. These associations are often unpredictable and typically cannot be changed during normal operation. Because the initial network topology typically does not take into account the applications being executed between the client/server devices or the quality or characteristics of the associated communication channels, this initial network topology may produce unnecessary and inefficient traffic flow within the wireless network. Furthermore, by failing to provide mechanisms to enable the network to dynamically change the network topology and associated routing in response to changes in the client application or communication channels, this initial network topology can also produce significant quality of service (QoS) problems during subsequent operation. Accordingly, although existing network configuration approaches provide certain advantages in terms of flexibility and ease of use, these approaches can lead to a poor overall user experience due to the inability of the user to exert any meaningful control over the network topology and associated routing relationships.

Therefore, in light of the foregoing problems, there is a need for systems and methods for intelligent routing within wireless communication systems. These systems and

methods would preferably enhance the selection and configuration of the initial network topology and associated routing relationships and enable the wireless network to dynamically change the network topology and associated routing relationships in response to changes in the client application, required/available bandwidth, existing frequency interference and other factors, all in accordance with user preferences.

Embodiments of the present invention alleviate many of the foregoing problems by providing systems and method for intelligent routing within wireless communication systems. In one embodiment, a user definable routing profile stores user definable selection criteria for selecting among routing relationships between a client device and a server device. When a client device initially attaches to the wireless network, this user definable routing profile may be used to select among the available routing relationships between the client device and the server device. If a particular routing relationship satisfies the user definable selection criteria stored in the routing profile, this routing relationship is selected and is used to establish a connection between the client device and the server device. This process allows data traffic to be routed between the client device and server device in accordance with the desired routing relationship specified by the user.

Other embodiments provide mechanisms for monitoring the established connection to determine whether the established connection continues to satisfy the user definable selection criteria. If the established connection ceases to satisfy the user definable selection criteria due to a change in the quality or characteristics of the established connection, the established connection may be rerouted between the same client device and the same server device using a different routing relationship specified in the user definable routing profile. Alternatively, if the established connection ceases to satisfy the user definable selection criteria due to a change in the client application or a change in the server device used to service the client application, the established connection between the client device and the server device may be deactivated, and a second connection between the client device and a different server device may be activated in accordance with the stored user definable routing profile. These processes allow routing relationships between the client device and server device to adapt to changes in the client application or quality or characteristics of the associated communication channels.

Still other embodiments provide different types of selection criteria to enable the selection of appropriate routing relationships between the client device and the server device. For example, the user definable selection criteria may comprise rules for selecting

amoung routing relationships based on the user application to be serviced between the client device and the server device, thereby enabling application awareness in the selection of the routing relationship. The user definable selection criteria may also include rules for selecting among routing relationships based on at least one of: a shortest route, a received signal strength indicator, a required bandwidth, and an available bandwidth between the client device and the server device, thereby enabling the selected routing relationship to take into consideration the quality or characteristics of the communication channels between the client device and server device. These selection criteria may be used to determine the initial routing relationship between the client device and the server device at the time the client device initially connects to the network, or whether to initiate a re-configuration of the network topology and associated routing relationships in response to changes in the client application and/or channel characteristics.

It should be noted that the foregoing mechanisms may be implemented in the client device to the enable client-initiated selection and control over traffic routing and re-routing. Alternatively, the foregoing mechanisms may be implemented in a centralized controller to enable centralized control over the routing and re-routing of data traffic of all client/server devices within the network in accordance with user preferences. These alternative embodiments enhance the flexibility of implementation and control offered by embodiments of the present invention.

By providing mechanisms to enable intelligent routing within wireless communication system, embodiments of the present invention alleviate many of the problems associated with the relatively static and ad hoc manner in which network topology are typically determined. Other embodiments of the present invention also provide certain advantages by enabling a more appropriate configuration of initial routing relationships and by enabling the routing within the wireless network to adapt to changes in the client application, required/available bandwidth, existing frequency interference and other factors, in each case, in accordance with user preferences.

These and other features and advantages of the present invention will become more apparent to those skilled in the art from the following detailed description in conjunction with the appended drawings in which:

Figures 1A, 1B and 1C illustrate exemplary wireless communication systems in accordance with one embodiment of the present invention;

Figure 2 illustrates an exemplary routing controller in accordance with one embodiment of the present invention;

Figure 3 illustrates an exemplary network database that may be used in accordance with embodiments of the present invention; and

Figure 4 illustrates an exemplary method in accordance with one embodiment of the present invention.

Embodiments of the present invention provide systems and methods for intelligent routing within wireless networks. The following description is presented to enable a person skilled in the art to make and use the invention. Descriptions of specific applications are provided only as examples. Various modifications, substitutions and variations of the preferred embodiment will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments and applications without departing from the scope of the invention. Thus, the present invention is not intended to be limited to the described and illustrated embodiments, and should be accorded the widest scope consistent with the principles and features disclosed herein.

Referring to Figures 1A, 1B and 1C, exemplary wireless communication systems in accordance with one embodiment of the present invention are illustrated generally at 100. As illustrated, the exemplary systems include client devices 110, server devices 120, a router 130 and a gateway 140 that are connected to one another via connections 150 to form the network topology and associated routing relationships of the exemplary systems. As is often the case, a particular network topology and associated routing relationships may produce desirable results for one type of application or client/server connection, but undesirable results for other types of applications or client/server connections. For example, the network topology of Figure 1A may produce desirable results for audio streaming applications between client 110a and server 120a, but undesirable results for Internet applications between client 110a and gateway 140 and video streaming applications between client 110a and server 120b. Similarly, the network topology of Figure 1B may produce desirable results for Internet applications between client 110a and gateway 140, but undesirable results for audio streaming applications between client 110a and server 120a and video streaming applications between client 110a and server 120b. Because the network topology and associated routing relationships are typically determined in an ad hoc manner and cannot be changed during normal operation, the applicable network configuration protocol may be unable to produce a network topology and associated routing

relationships that conform to the user's preferences for all applications or client/server connections.

As will be described in greater detail below, embodiments of the present invention alleviate many of these problems by providing a user definable routing profile and associated routing manager for providing intelligent routing within the wireless network in accordance with user preferences. The user definable routing profile may be configured to store user definable selection criteria for selecting among network topologies and associated routing relationships between client devices 110 and server devices 120. This selection criteria may comprise a set rules that define the desired routing relationships that a client device 110 should employ based on, for example, the client application to be executed by the client device 110, the server device 120 that services that client application, the shortest route between the client device 110 and the server device 120, the required bandwidth of the application, the available bandwidth of the network connections 150, a received signal strength indicator (RSSI) or frequency interference measurements of the network connections 150, or other parameters.

When a client device 110 desires to initially attach to the wireless network 100, the routing manager may be configured to use the stored routing profile to select the network topology and associated routing relationships that satisfy the user definable selection criteria. For example, the routing manager may be configured to discover the routers 130 and gateways 140 to which the client device 110 may attach and the associated routing relationships between the client device 110 and server devices 120 by, for example, multicasting the client device's static IP address and assembling the routing information received from the routers 130 and gateways 140 that respond. The routing manager may then use the user definable selection criteria, the received routing information, and other information regarding the intended client application and client/server connection to select the routing relationship between the client device 110 and server device 120. The client device 110 may then attach to the router 130 or gateway 140 such that the routing relationship between the client device 110 and the server device 120 conforms to the selected routing relationship specified in the routing profile.

The routing manager may also be configured to monitor the established connection between the client device 110 and the server device 120 to determine whether the established connection continues to satisfy the user definable selection criteria. If the established connection ceases to satisfy the user definable selection criteria due to a change

in the quality or characteristics of the established connection, the established connection may be rerouted between the same client device 110 and the same server device 120 using a different routing relationship specified in the user definable routing profile. Alternatively, if the established connection ceases to satisfy the user definable selection criteria due to a change in the client application or a change in the server device 120 used to service the client application, the client device 110 may be configured to terminate the established connection with the server device 120, and establish a second connection between the client device 110 and a different server device 120 in accordance with the user definable routing profile. By continuing to monitor the established connection, the routing manager enables the routing relationships between client devices 110 and server devices 120 to adapt to changes in the client application or quality or characteristics of the associated communication channels such that the routing relationships continue to satisfy the user definable selection criteria during subsequent operation.

To illustrate the foregoing processes, if client device 110a desires to initially attach to the wireless network 100 and perform an audio streaming application with server 120a, the routing manager associated with client device 110a multicasts the IP address of client device 110a and assembles the routing information received from router 130 and gateway 140, which routing information the routing manager stores in a network database for later use. The routing manager then compares the received routing information to the user definable selection criteria stored in the routing profile. If the routing manager determines that the routing relationship associated with router 130 satisfies the selection criteria, then client device 110a will attach to router 130 to form the network topology and associated routing relationship between client device 110a and server device 120a that is illustrated in Figure 1A.

If client device 110a is already attached to the wireless network 100 in accordance with the network topology illustrated in Figure 1A and desires to perform an Internet application with gateway 140, the routing manager will detect that the client application and/or associated server has changed and will determine whether to modify the existing routing relationship between client device 110a and gateway 140. In this case, the routing manager will compare the routing information stored in the network database to the user definable selection criteria stored in the routing profile. If the routing manager determines that a direct connection with gateway 140 better conforms to the user definable selection criteria, then client device 110a will terminate the connection with router 130, and establish

a new connection with gateway 140 to form the network topology and associated routing relationship between client device 110a and gateway 140 that is illustrated in Figure 1B.

If client device 110a is already attached to the wireless network 100 in accordance with the network topology illustrated in Figure 1B and desires to perform a video streaming application with server 120b, the routing manager will similarly detect that the client application and/or associated server has changed and will determine whether to modify the existing routing relationship between client device 110a and server 120b. If the routing manager determines that the routing relationship via gateway 140 continues to conforms to the selection criteria, then client device 110a will maintain the connection with gateway 140 such that the data is routed between client device 110a and server 120b in accordance with the network topology and associated routing relationship illustrated in Figure 1B. The routing manager, however, will continue to monitor the connection between client device 110a and server 120b for changes in the required bandwidth of the application, the available bandwidth of the network connections 150, a received signal strength indicator (RSSI), frequency interference measurements of the network connections 150, etc. If the routing manager determines that the routing relationships illustrated in Figure 1B no longer satisfy the user definable selection criteria and that the routing relationships illustrated in Figure 1C does satisfy the selection criteria, the routing manager may initiate a reroute of data traffic by terminating the connection with gateway 140, establishing a new connection with router 130, and causing router 130 to establish a connection with server 120b to form the network topology and associated routing relationships illustrated in Figure 1C.

By providing mechanisms to enable intelligent routing within wireless communication system, embodiments of the present invention alleviate many of the problems associated with the relatively static and ad hoc manner in which network topology are typically determined. Embodiments of the present invention also provide certain advantages by enabling a more appropriate configuration of initial routing relationships and by enabling the routing within the wireless network to adapt to changes in the client application, required/available bandwidth, existing frequency interference and other factors, in each case, in accordance with user preferences. It should be also be noted that the foregoing mechanisms may be implemented in the client devices 110 to the enable client-initiated selection and control over traffic routing and re-routing, or in a centralized controller 160 to enable centralized control over the routing and re-routing of data traffic of all client/server devices within the network in accordance with user preferences.

Accordingly, the descriptions of the foregoing processes performed by the routing manager and associated routing profile would be equally applicable in either of these alternative embodiments.

Referring to Figure 2, an exemplary routing controller in accordance with one embodiment of the present invention is illustrated generally at 200. This exemplary routing controller may be implemented in a client device to the enable client-initiated selection and control over traffic routing and re-routing, or in a centralized controller to enable centralized control over the routing and re-routing of data traffic of all client/server devices in accordance with user preferences.

As illustrated, the exemplary routing controller includes a user definable routing profile 245 and a network control layer 210. The user definable routing profile 245 further includes user definable selection criteria 247 that contain rules for selecting among routing relationships between client and server devices and (optionally) user definable configuration parameters 246 that contain information for configuring connections between the client and server devices. A visualization tool 270 may be coupled to the routing profile 245 to display to the user the current configuration parameters 246 and selection criteria 247 stored in the routing profile 245. A configuration tool 260 may also be used to provide a user interface that enables users to create, delete or modify the existing configuration parameters 246 and selection criteria 247.

The network control layer 210 illustrated in Figure 2 further includes a routing manager 220 and a network database 230. As was previously discussed, the routing manager 220 is responsible for selecting initial routing relationships to be employed by a client device and initiating subsequent re-configuration of the routing relationships in accordance with the selection criteria 247 stored in the routing profile 245. In this context, the routing manager 220 may be configured to interface with a data link control layer 240 to gather routing information received from routers and gateways. The routing manager 220 may then store the received routing information in the network database 230 for subsequent use in, for example, the format illustrated in Figure 3. The routing manager 220 may also interface with the data link control layer 240 in order to monitor the quality or characteristics of the applicable communication channels, such as a received signal strength indicator (RSSI), measured interference, and available bandwidth. The routing manager 220 may further gather information regarding the client applications 250 to be executed

between the client device and server device, such as the type of application, the intended server that services that application, and the required bandwidth of the application.

Using this information, the routing manager 220 may then compare the available routing relationships stored in the network database 230 with the user definable selection criteria stored in the routing profile 245. If one of the available routing relationships satisfies the selection criteria 245, the routing manager 220 selects that routing relationship and establishes a connection between the client device and the server device such that data traffic is routed between the client device and server device in accordance with the selected routing relationship. Alternatively, the routing manager 220 may select the routing relationship specified by the selection criteria 247, and send appropriate signals to the data link control layer 240 to request a re-configuration of the network topology (e.g., by establishing a connection with a router and requesting that the router establish a new connection with the intended server). If the network topology is successfully re-configured, the routing manager 220 will update the network database 230 with the new routing relationships.

Once a connection is established, the routing manager will continue to monitor the established connection and the client applications 250 to determine whether the established connection continues to satisfy the selection criteria 247. If the establish connection ceases to satisfy the selection criteria 247, the routing manager 220 sends appropriate signals to the data link layer 240 to either re-route the connection between the same client device and the same server device using a different routing relationship specified in the user definable routing profile, or deactivate the established connection between the client device and the server device and activate a second connection between the client device and a different server device in accordance with the stored user definable routing profile. Of course, the routing manager 220 may perform the foregoing processes by either selecting a different available routing relationship or requesting a re-configuration of the network topology as described above. In any event, the routing manager 220 provides intelligent routing within the wireless network by assuring that the routing of traffic between client devices and server devices conform to the user definable selection criteria.

Referring to Figure 4, an exemplary method in accordance with one embodiment of the present invention is illustrated generally at 400. As illustrated, when a device desires to initially attach to the wireless network, the device initiates the exemplary method at step 410 by multicasting its static IP address. At step 420, the device assembles the information

that is received in response the multicast message to discover the nodes (e.g., routers or gateways) to which the device may attach and the available routing relationships within the wireless network. Using the received routing relationships and the stored user definable selection criteria, the device may then attach to the node that satisfies selection criteria at step 430 such that data will be routed between client/server devices in accordance with the routing relationships specified by the selection criteria.

Once a connection between a client and server device has been established, the established connection is monitored at step 440 to determine whether to initiate re-route. This process may involve examining the quality or characteristics of the established connection, the application being executed by the client device, or the server that is servicing that application to determine whether the established connection continues to satisfy the selection criteria. If the established connection satisfies the selection criteria, the exemplary method proceeds back to step 440 to continue monitoring the established connection. If the established connection does not satisfy the selection criteria, the device will re-route data traffic between the client server device in accordance with the selection criteria. This process may involve selecting a different one of the available routing relationships, terminating the established connection and establishing a new connection, or requesting a re-configuration of the network topology. If the network topology has changed, the exemplary method proceeds to step 460 to update the network database and then to step 440 where the new routing relationship is monitored to determine whether initiate another re-route.

While the present invention has been described with reference to exemplary embodiments, it will be readily apparent to those skilled in the art that the invention is not limited to the disclosed and illustrated embodiments but, on the contrary, is intended to cover numerous other modifications, substitutions and variations and broad equivalent arrangements that are included within the scope of the following claims.